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EVALUATION OF LIQUEFACTION POTENTIAL USING CONE PENETRATION TEST FOR RAPTI MAIN CANAL

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ABSTRACT

During the earthquake Soil liquefaction is the major concern for demolishing the structurealong the rivers, tributaries and the valley floors. This paper shows the evaluation of liquefaction potential using the Cone Penetration Test (CPT) at a project under the SaryuNaharPariyojna in the basins of Rapti River named as Rapti Main Canal in Balrampur areas. This is the leading distributary project which have a stretch of 125 km through the Balrampur, Behraich and Shravasti districts of Uttar pradesh. This area of Rapti Main Canalhaving a major concern about the soil Liquefaction due its soil behavior and water logging, here mostly we found sandy soil in saturated state. The objective of this paper is to evaluate soil liquefaction in term of factor of safety using method of Cone Penetration test given by the P.K. Robertson and C.E. (Fear) Wride in 1998 and updated work in Robertson 2009, CPT provide good evaluation of Liquefaction Potential due its continuous in nature.

KEYWORDS: Soil Liquefaction, Cone Penetration Test, Cyclic Stress Ratio, Cyclic Resistance Ratio, Soil Behaviour Type Index

INTRODUCTION

Earthquake is the most dangerous natural disaster due to its unpredictability and devastating in nature. They are not only cause grate destructive in terms of human life but its also impacts economically on the affected area. And liquefaction is one of the causes of earthquake destruction in which saturated soil can fail its shear strength and behave like a mud. The phenomenon of liquefaction has been seen after Nigata (1964) and Alaska (1964) earthquake. Earthquake reduces the strength and stiffness of soil by shaking and other rapid loading.

Soil liquefaction are related to ground failures which are commonly occurred with large earthquakes. Soil liquefaction commonly refers to the loss of strength in cohesionless and saturated soils due to the build-up of pore water pressures during shaking of ground. “It is a phenomenon where soil mass loses a large percentage of shear resistance, when its subjected to cyclic, monotonic, shock loading, and flows in a manner assembling a liquid up to the shear stresses acting on the mass are low as the reduced shear resistance.”

There are various methods for the assessment of soil liquefaction potential i.e. **(i)** standard penetration test (SPT) **(ii)** cone penetration test (CPT) **(iii)** shear wave velocity (Vs) measurement **(iv)**Becker penetration test (BPT). From these various method CPT is most frequent and good in nature due to its continuity

In past number of CPT-based liquefaction-triggering correlations have been published, but only the most frequently used correlation to date is that proposed by Robertson and Wride (1998) as presented in NCEER (1997) and Youd et al. (2001). This work provides the most usable and comprehensive CPT-based assessment of liquefaction triggering available. Some of the deficiencies of this work include lack of probabilistic assessment, inconsistent treatment and processing of the field case histories, unconservative assessment of the effects of “fines” on soil liquefiability, and overly simplified treatment of normalization of CPT tip resistance for effective overburden stress effects. The result is a methodology with an undefined level of uncertainty, and one that is unconservative in soils with a significant percentage of fines.

Other well-known studies, including Shibata and Teparaska (1988), Stark and Olson (1995), Suzuki et al. (1995), all employ a more limited database of field performance case histories than Robertson and Wride (1998). On the theoretical side, Mitchell and Tseng (1990) presented a correlation that was based on cavity expansion analyses, validated with laboratory cyclic simple shear and cyclic triaxial testing data. This work is valuable for bounding empirical results and providing a theoretical backbone but is based on a limited amount of data. Recent work by Juang et al. (2000, 2003) presents probabilistic results but uses a database with the same deficiencies as Robertson and Wride (1998)

Study Area

This **study** is on Rapti Main Canal which occurs under the SaryuNaharPariyojna. Rapti Main Canal having a stretch of 125 km long its capacity is about 95 cumec through Balrampur, Behraich and Shravasti districts of Uttar pradesh.

For the study we analyze the CPT data of nine village through which the canal is passes these areas are in the district of Tulsipur, Balrampur and in Shravasti. These areas are lies in the Shivalic range of Himalaya and near to the Rapti River. Water logging is the major problem in this area.

Geological Condition of the Study Area

Balrampur lies on the bank of Rapti River it located at the 27.43°N latitude and 82.18°E longitude. Ithas an average elevation of 105 meter.Balrampur is situated on the bank of bank of Rapti River. Its shear his boundaries with Nepal for northern side, Gonda districts from south sides and Siddhartnagar from east-west side. In the north of Balrampur Districts is situated the Shivalik Hills of the Himalayas Mountains.

All the rivers of Balrampur District flow from north-west to south-east and belong to two main systems that of Rapti in the north and Ghaghara River in the south. Each is fed by numerous tributaries. The Rapti rises in the mountains of Nepal, and after traversing Bahraich District enters district Gonda. Its banks are usually high, but the river is continually changing its course. It only overflows its banks in wet seasons. On either side of Rapti River, but especially on the north, the country is cut up by innumerable deserted channels of the river. Many of these contain water for a part of the year only. But the only one which can be considered as a definite stream is that know as the BurhiRapti which emerges near Mathura and flow across the district in a direction roughly parallel to that of the Rapti. Kuwana River flows with slow speed and Bishuhi River joins Kuwana. It covers very small part of the district.

Balrampur are in the Earthquake High Damage Risk Zone-IV. This zone is also called the high damage risk zone, IS code assign zone factor of.**24** for Zone-IV. This city located at the foothills of Himalayas and characterized under Zone IV, which is second highest seismic risk zone. Maximum land area of India about 59% are lies in risk Zone III, IV and V.

Assessment of Liquefaction Potential

This work is done for determining the liquefaction of RAPTI CANAL using cone penetration test (CPT) method. In this work, CPT based liquefaction models from geotechnical earthquake engineering are used in combination with random field models to assess the liquefaction potential at different bore. The following steps are followed to determine the liquefaction potential.

STEP -1ST

Identify the region of interest and collect the characterized data from different bore hole by the available field test for liquefaction assessment (e.g., CPT soundings, water table, and soil unit weights).

STEP-2nd

Characterizing the obtained field data directly (e.g., tip resistance and side friction from CPT soundings) and then using that data to further characterize the random field models.

STEP-3rd

The value for total vertical stress (σ_{vo}) and effective vertical stress (σ'_{vo}) form the laboratory test of soil sample and field data calculation.

STEP-4th

Evaluation of the seismic demand on a soil layer placed by a given earthquake, expressed in terms of the cyclic stress ratio (CSR). For CSR adopt the adjusted formula suggested by Juang et al. 2006. Which is given as follows;

$$CSR = 0.65\left(\frac{a_{max}}{g}\right)\left(\frac{\sigma_{vo}}{\sigma'_{vo}}\right)(r_d)\left(\frac{1}{MSF}\right)\left(\frac{1}{K_\sigma}\right)$$

Where,

- a_{max} is the peak horizontal acceleration at ground surface generated by earthquake
- g is the acceleration of gravity
- σ_{vo} total vertical overburden stress
- σ'_{vo} is the effective vertical overburden stress
- r_d is the depth-dependent shear stress reduction coefficient, we adopt it from the research work of yound et al. 2001,which is given as follows;

$$r_d = \frac{(1.0-0.4113z^{0.5}+0.04052z+0.00153z^{1.5})}{(1.0-0.4177z^{0.5}+0.5729z-0.00620z^{1.5}+0.001210z^2)}$$

- MSF is the magnitude scaling factor, for MSF lower-bound equation in Youd et al.2001 is used

$$MSF = \frac{10^{2.24}}{M_w^{2.56}}$$

STEP-5th

Evaluation of soil behavior type index (I_c), which is adopted from the suggested formula by Robertson and Wride 1998. Is given as follows;

$$I_c = \sqrt{(3.47 - logQ)^2 + (1.22 + logF)^2}$$

Where, Q is normalized tip resistance and F is normalized friction ratio, which is give as follows;

$$Q = \left(\frac{q_c - \sigma_{vo}}{\sigma'_{vo}}\right)$$

And, $F = \left(\frac{f_s}{q_c - \sigma_{vo}}\right) \times 100\%$

STEP-6th

Evaluation of the cyclic resistance ratio CRR which is adopted by the research work of Robertson and Wride 1998 and updated work in Robertson 2009. Which is given as follows;

$$CRR = 0.833[(q_{C1N})_{cs}/1000] + 0.05$$

$$if\ (q_{C1N})_{cs} < 50$$

$$CRR = 93[(q_{C1N})_{cs}/1000]^3 + 0.08$$

$$if\ 50 \leq (q_{C1N})_{cs} < 160$$

Where,$(q_{C1N})_{cs}$ is clean sand equivalence of the normalized cone tip resistance, which is defined as follows:

$$(q_{C1N})_{cs} = K_c q_{C1N}$$

$K_c$is conversion factor, which is defined as follows,

$$K_c = 1\ for\ I_c \leq 1.64$$

$$K_c = -0.403 I_c^3 - 5.581 I_c^2 + 33.75 I_c - 17.88$$

$$for\ I_c > 1.64$$

$q_{C1N}$is the adjusted Cone Penetration Resistance which is defined by Robertson and Wride 1998 as follows;

$$q_{C1N} = \left(\frac{q_c - \sigma_{vo}}{P_{at}}\right)\left(\frac{P_{at}}{\sigma'_{vo}}\right)^n$$

Where, $P_{at} = 1atm$ of pressure (100 kPa)

q_c = cone penetration resistance

n = stress exponent, which is given by Robertson 2009 in his update

$$n = 3.81 I_c + 0.05\left(\frac{\sigma'_{vo}}{P_{at}}\right) - 0.15$$

$$where\ n \leq 1$$

STEP-7th

Evaluation of factor of safety against liquefaction potential is defined as follows;

$$FS = \frac{CRR}{CSR}$$

Where, CRR represents Cyclic Resistance Ratio and CSR represents Cyclic Stress Ratio.

RESULT AND DISCUSSIONS

The value of Factor of Safety (FS) less than one and grater then one at certain depth respectively indicate that the soil layer at specific depth is liquefiable on non-liquefiable. We have evaluated the Factor of safety for 19 bore hole from 9 different sites. Balrampur reason is occur in seismic Zone IV for which we take a_{max} is.24g and MSF of magnitude 8. These sites and there test results are discussed below through table and bar chart-

Table 1

S.N.	Location of Bhore Hole	Bore Hole No	Liquefiable Depts	Non Liquefiable Depths
1.	VILLAGE BAHDINWA NALA, HARRAIYA ROAD, TULSIPUR Dist. BALRAMPUR	BH-1	0.50-4.00 m, and 6.00-7.00 m	4.50-5.50 m and 7.50-10 m
		BH-2	0.50-5.50 m	5.50-7.50 m
		BH-3	0.50-8.50 m	9.00-10.00 m
2.	VILLAGE GAURA MAFI, Dist. BALRAMPUR	BH-4	0.50-4.00 m and 7.00-8.50 m	4.50-6.50 m and 9.00
		BH-5	0.50-5.50 m and 7.00-8.50 m	6.00-6.50 m and 9.00-9.50 m
3.	VILLAGE GULWARIA, Dist. SHRAVASTI/BALRAMPUR	BH-6	0.50 -7.00 m	7.50-9.00 m
		BH-7	0.50-8.00 m	8.50-9.00 m
4.	VILLAGE TEDHI PRAS, Dist. SHRAVASTI/BALRAMPUR	BH-8	0.50-10	-
		BH-9	0.50-7.50 m and 9-9.5	8.00-8.50 and 10-11.00 m
5.	VILLAGE LACHHAWAPUR, Dist. SHRAVASTI/BALRAMPUR	BH-10	0.50-6.5 m, 7.5 m and 9.00-9.50 m	7.00 m 8.00-8.50 m and at 10 m
		BH-11	0.50-8.00 m and 9.50 m	8.50-9.00 m
6.	VILLAGE SIGRAURA, Dist. TULSIPUR/BALRAMPUR	BH-12	0.50-11.00 m	11.50-12.00 m
		BH-13	0.50-6.00 m and 7.00-7.50 m	6.50 m and 8.50-9.00 m
7.	VILLAGE BHALUHIAN, Dist. BALRAMPUR	BH-14	0.50-8.50 m and 9.50-10.00 m	9.00 m and 10.50-11.00 m
		BH-15	0.50-8.50 m, and 9.50-10.50 m	9.00 m and at 11.00 m
8.	AT VILLAGE RAMWAPUR DEVNAGAR, Dist. TULSIPUR/BALRAMPUR	BH-16	0.50-7.00 m	7.50-10.00 m
		BH-17	0.50-8.00 m	8.50-10.00 m

Table 1: Contd.,				
9.	VILLAGE LALPUR, Dist. TULSIPUR/BALRAMPUR	BH-18	0.50-5.00 m, and 6.00-8.00 m	5.50 m and 8.50-10.00 m
		BH-19	0.50-7.50 m, and 8.50-10.00 m	8.00 m

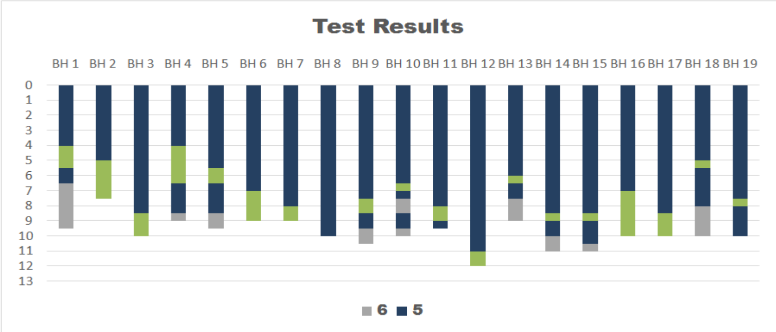

Figure 1

CONCLUSONS

This paper discusses the evaluation of seismically induced Liquefaction based on semi-empirical field based procedure for earthquake Moment Magnitude, M=8.

From above tests it is clear that for the maximum depths of soil will be liquefiable, thus for the construct the canal in this region mitigation is required because the safe depths are different at different location. This region is located at second highest seismic risk zone.

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